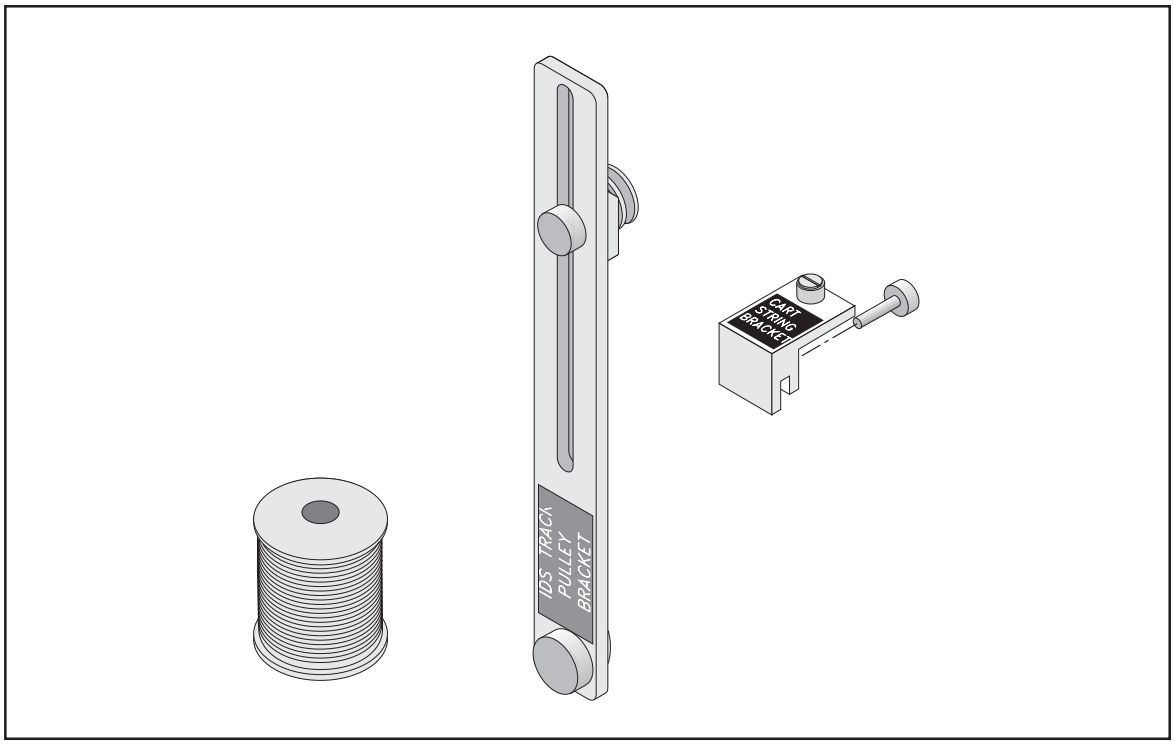
Includes
Teacher's Notes
and
Typical
Experiment Results

Instruction Manual and Experiment Guide for the PASCO scientific Model ME-6569

012-06408A
6/97

RMS/IDS KIT



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Introduction

The PASCO CI-6569 RMS/IDS Kit allows the PASCO CI-6538 Rotary Motion Sensor (RMS) to function as a Smart Pulley for measuring the absolute location of a PASCO Dynamics Carts (ME-9430 or ME-9454) running on PASCO Introductory Dynamics System Tracks (ME-9429A or ME-9452).

The *IDS track pulley bracket* and the *cart—string bracket* included in the RMS/IDS Kit, together with the required IDS Mount Accessory (CI-6692), allow the connection of the Dynamics Cart to the large pulley of the RMS with a sturdy thread. The thread is anchored on the Dynamics Cart and passed over the large pulley on the RMS, allowing bidirectional linear motion of the Dynamics Cart to be logged into *Science Workshop*™ through a PASCO computer interface (500 or 700). *Science Workshop* can then display the motion data in terms of absolute location, velocity, and acceleration.

Two sets of Dynamics Carts, Rotary Motion Sensors, and connecting brackets can be installed on a single Dynamics Track to allow simultaneous measurement of linear motion of two carts (700 interface only).

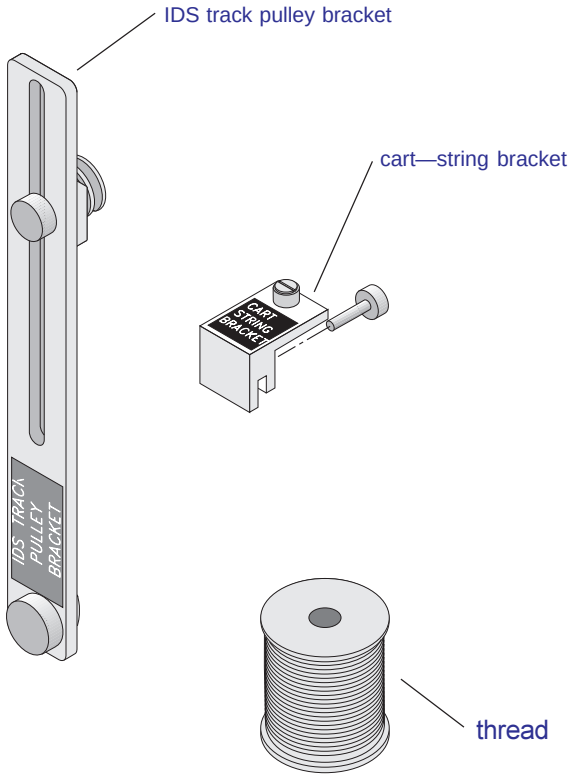
Equipment

Included:

- IDS track pulley bracket
- cart—string bracket
- spool of sturdy thread

Additional Required:

- Rotary Motion Sensor (CI-6538)
- IDS Mount Accessory (CI-6692)
- Dynamics Cart (ME-9430 or ME-9454)
- Dynamics Track (ME-9429A or ME-9452)
- PASCO computer interface (500 or 700)
- *Science Workshop* version 2.2 or higher
- computer



Setup

Equipment

1. Mount the Rotary Motion Sensor (RMS) on the IDS track with the IDS Mount Accessory so the RMS can be used like a Smart Pulley (see IDS Mount Instruction Sheet and Figure 3).
2. Mount the IDS track pulley bracket on the same side of the track at the other end (Figure 1).
3. Mount the cart—string bracket on the cart (Figure 2).

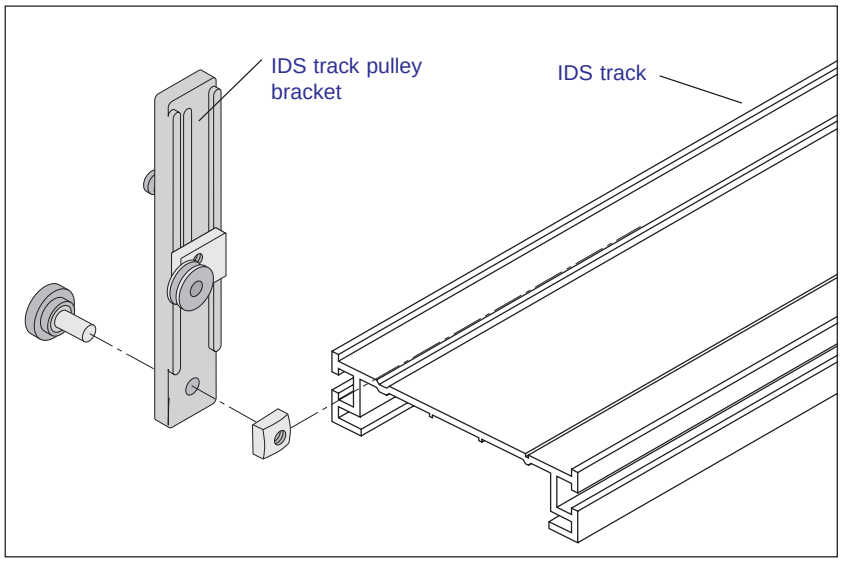


Figure 1
Mounting the IDS track pulley bracket on the IDS track

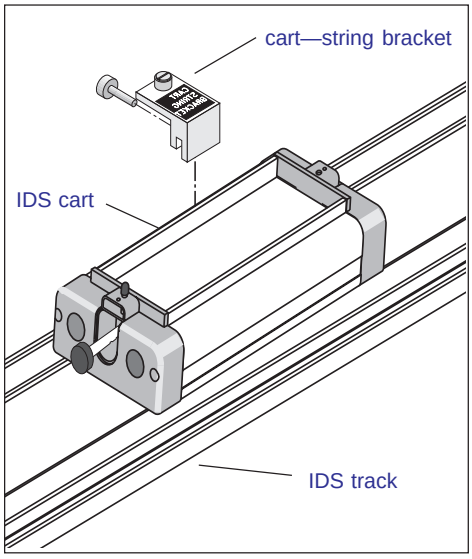


Figure 2
Attaching the cart—string bracket to the Dynamics Cart

4. Cut a length of thread about 2.5 m long (for the 1.2 m track). Anchor one end of the thread under the screw of the cart—string bracket on the cart. Thread the string over and under the large pulley of the RMS (Figure 3).
5. Pull the thread under and over the top of the small pulley on the bracket.
6. Pull the thread taunt and secure the end under the thumbscrew of the cart—string bracket.
7. Adjust the height of the large and small pulleys so the top half of the string is horizontal and so the bottom half moves without being obstructed by the track or brackets (Figure 3).

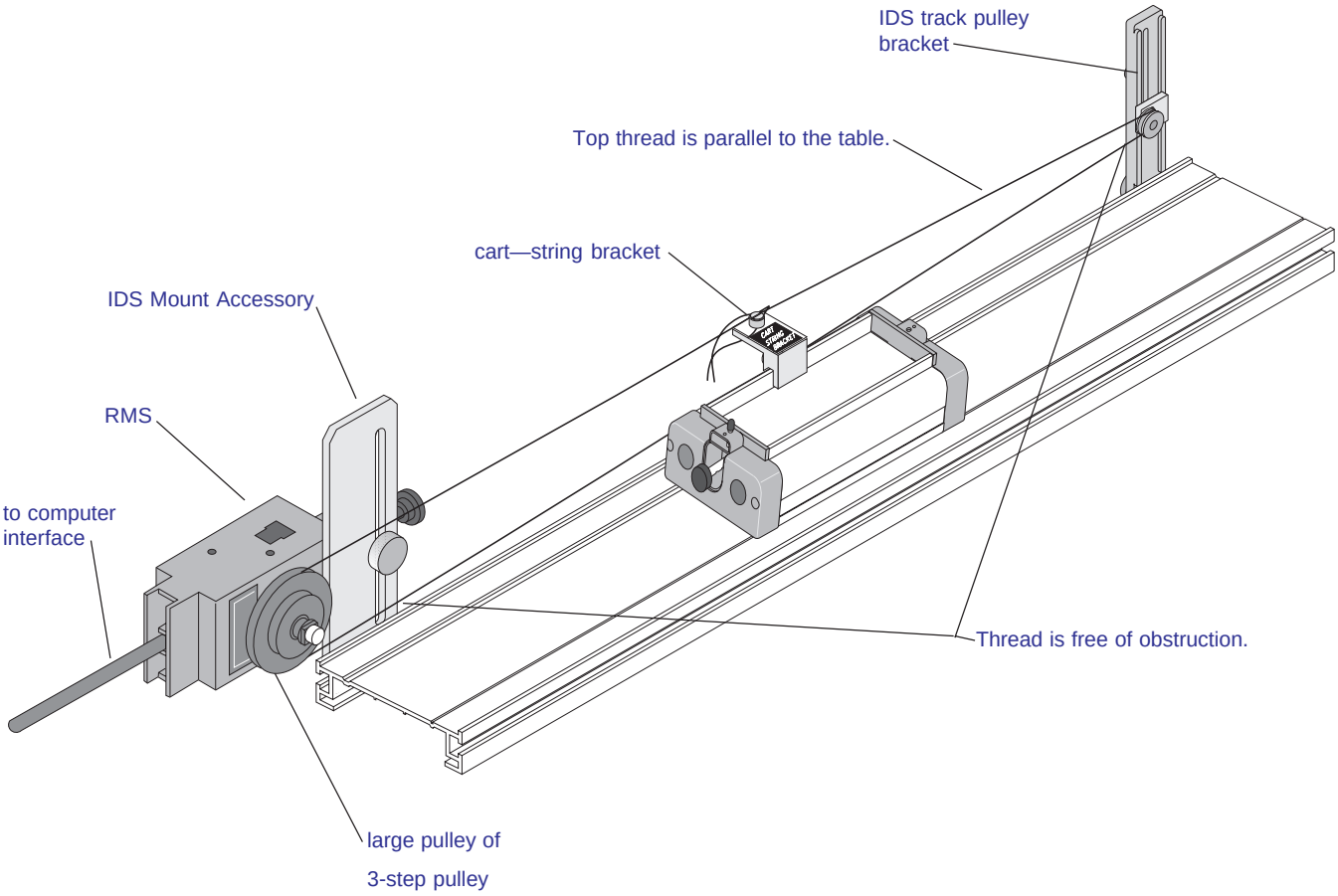


Figure 3
Completed assembly

8. If necessary, adjust the tension of the string by moving the IDS track pulley bracket along the track.

Science Workshop

1. Insert the digital plugs of the the RMS into digital ports 1 & 2 or 3 & 4 of the computer interface box.
2. Open *Science Workshop* and set up the RMS in the setup window (refer to the RMS manual (012-06053A for details).
3. Double-click on the RMS icon ( ) and choose **Large Pulley (Groove)** in the **Linear Calibration** dialog box. Click **OK**.

➤ ***Note:*** ***The manual has been written with the assumption that the user has a basic familiarity with Science Workshop and has access to the "User's Guide" for Science Workshop. Users can gain basic skills with Science Workshop by viewing the training video and by doing the tutorial within Science Workshop. Another useful resource is the "Quick Reference Card" for Science Workshop.***

Experiment 1: Correlation of velocity and acceleration vectors for a cart undergoing an elastic collision

Purpose

The purpose of the experiment is to develop a correlated, graphic display of the position, velocity, and acceleration of a cart during an elastic collision.

Materials and Equipment Required

- Rotary Motion Sensor (RMS) (CI-6538)
- RMS/IDS Kit
- IDS Mount Accessory (CI-6692)
- Dynamics Cart (ME-9430 or ME-9454)
- pages 2 and 3 of this manual
- Dynamics Track (ME-9435A or ME-9458)
- Adjustable End Stop (ME-9448A)
- PASCO computer interface (500 or 700)
- *Science Workshop* version 2.2 or higher
- computer

Procedure

Set Up the Equipment

1. Mount on the IDS track the RMS, using the IDS Mount Accessory, and the IDS track pulley bracket, as directed in the Equipment Setup section (pages 2 & 3) of this manual.

2. Attach the Adjustable End Stop to the end of the track (Figure 1.1). Move the IDS track pulley bracket, if necessary.

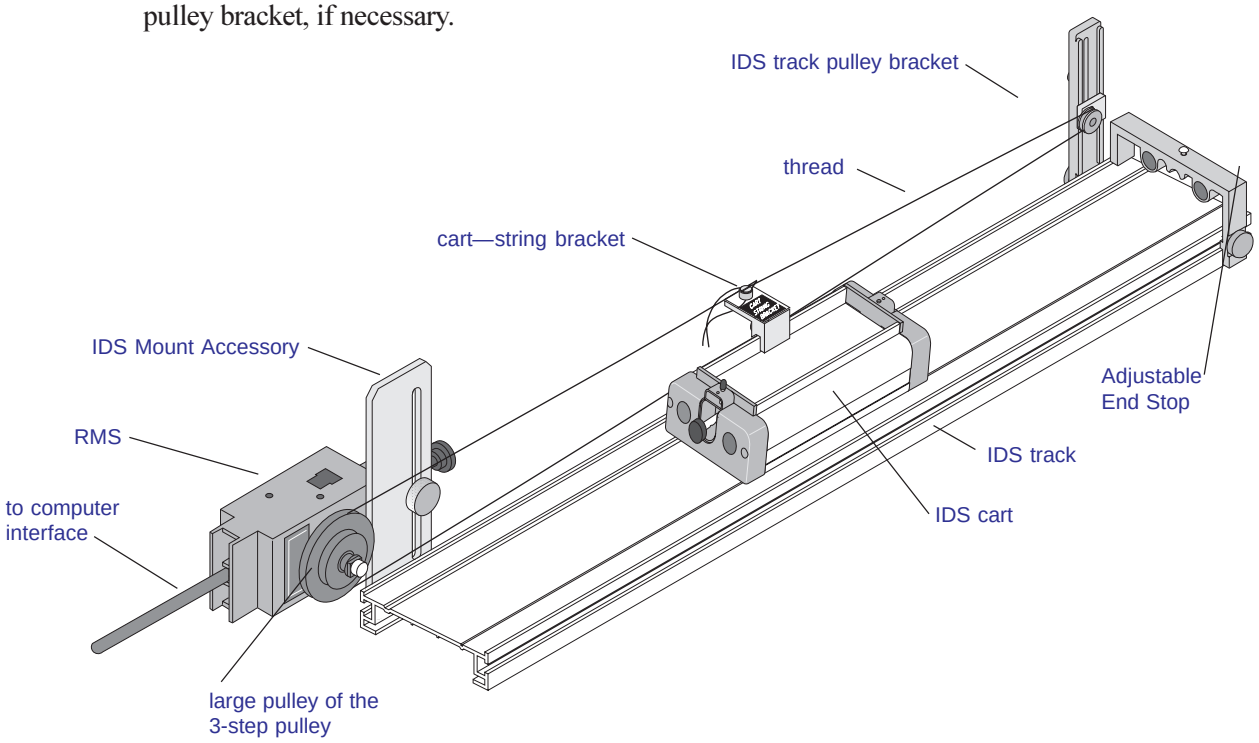


Figure 1.1
Equipment setup for experiment 1

3. Place the cart on the track with the magnets facing the Adjustable End Stop, and attach the cart—string bracket to the cart.

4. Thread the string as directed in the Equipment Setup section of this manual. Check to be sure the string moves freely without obstruction, is horizontal across the top of the pulleys and cart—string bracket, and is taunt enough so it does not slip on the pulleys.

Set Up *Science Workshop*

1. Set up the RMS in *Science Workshop* as directed in the setup section on page 3 of this manual.

2. If you are not in the setup window for the RMS, double-click on the RMS icon ( ).

3. Set the Division/Rotation to **1440**. Click **OK**.

4. Double-click on the Sampling Options button and set the sampling rate to **50 Hz**. Click **OK**.

5. Drag and drop a Graph display icon to the RMS icon and choose **Position (linPos)**, **Velocity (linVel),** and **Acceleration (linAcc)** from the **Choose Calculations to Display** pop-up menu.

Collect the data

1. Position the cart at the end of the track with the RMS.

2. Start recording data.

3. Give the cart a gentle push towards the end stop. (Use the amount of force needed for smooth movement of the cart.)

4. After the cart rebounds from the end stop, stop recording.

Analyze the data

1. Sketch the three graphs and label the axis (or print out the graph).

2. Label the graphs for the following: 1) cart moving towards the end stop; 2) the elastic collision of the cart; 3) cart moving away from the end stop.

Questions

1. Just before the collision, what is the velocity and acceleration of the cart?

2. Describe what happens to the cart's velocity during the collision. What is happening to the cart's position when it has negative velocity?

3. Describe what happens to the cart's acceleration during the collision. What is happening to the cart's position when the acceleration is changing from zero to negative? What is happening to the cart's position when the acceleration is changing from negative to zero?

Experiment 2: Comparison of momentum and impulse of an inelastic collision

Purpose

The purpose of the experiment is to quantitatively compare magnitude of the momentum of a moving cart with the impulse of its inelastic collision with a stationary object.

Materials and Equipment Required

- Rotary Motion Sensor (RMS) (CI-6538)
- RMS/IDS Kit (CI-6569)
- IDS Mount Accessory (CI-6692)
- Dynamics Cart (ME-9430 or ME-9454)
- Dynamics Track (ME-9435A or ME-9458)
- pages 2 & 3 of this manual
- ±50 Force Sensor (CI-6537)
- Force Sensor Bracket & Collision Bumpers (CI-6545)
- PASCO computer interface (500 or 700)
- *Science Workshop* version 2.2 or higher
- computer
- block of wood (or similar) about 10 cm in height

Theory

The momentum of a system is determined by the relationship:

$$P = mv$$

where P = momentum, m = mass, and v = velocity.

The *impulse*, or change in momentum, of a collision is determined by the relationship:

$$\Delta P = \int_{t_1}^{t_2} F dt$$

The area under the curve of a graph of the force versus time, as determined by integrating the curve, equals the total change in momentum.

In an inelastic collision, where the final velocity is zero, the following relationship exists:

$$mv = \int_{t_1}^{t_2} F dt$$

Procedure

Set Up the Equipment

1. Mount the RMS on the IDS track using the IDS Mount Accessory, and mount the IDS track pulley bracket on the IDS track (refer to the equipment setup section, pages 2 & 3, of this manual).

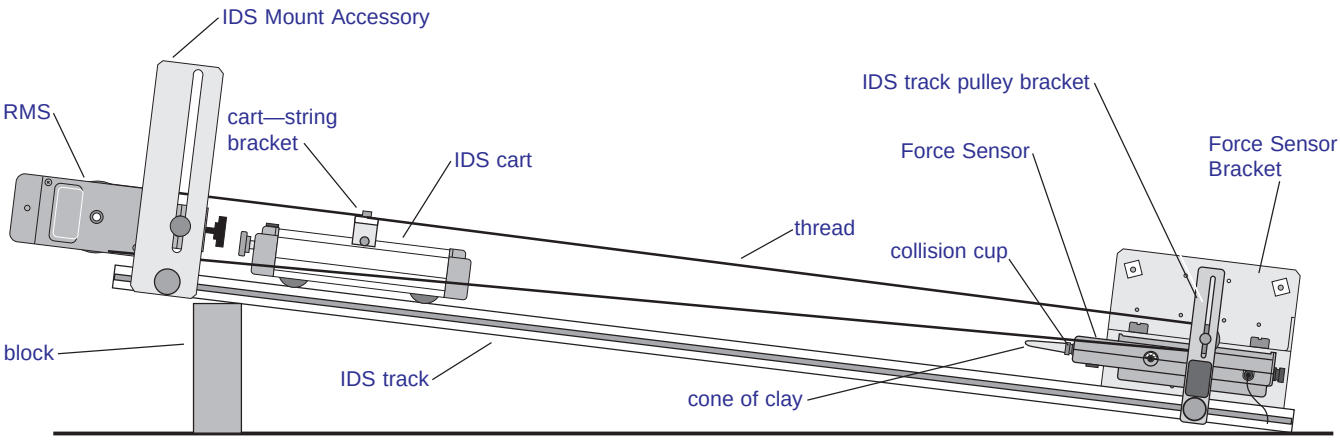


Figure 2.1
Equipment setup for experiment 2

2. Attach the Force Sensor to the end of the track using the Force Sensor Bracket (Figure 2.1). Move the IDS track pulley bracket, if necessary.

3. Unscrew the hook from the Force Sensor and replace it with the collision cup that is stored on the Force Sensor Bracket.

4. Make a cone of clay that is about 1 cm in base diameter and 3 cm in height, and press it onto the collision cup.

5. Place the cart on the track so the magnets face the Force Sensor.

6. Attach the cart—string bracket and connect the string as shown in the equipment setup section of this manual (page 2). Check to be sure the string moves freely without obstruction, is horizontal across the top of the pulleys and cart—string bracket, and is taunt enough so it does not slip on the pulleys.

Set Up *Science Workshop*

1. Set up the RMS in *Science Workshop* as directed in the setup section on page 3 of this manual.

2. If you are not in the setup window for the RMS, double-click on the RMS icon ( ).

3. Set the Division/Rotation to 1440. Click OK.

4. Double-click on the Sampling Options button and set the sampling rate to **50 Hz**. Click OK.

5. Drag and drop a Graph display icon to the RMS icon and select **Velocity (LinVel)** from the **Choose Calculations to Display** pop-up menu.

6. Set up the Force Sensor in *Science Workshop* (refer to the manual for the Force Sensor for details.

7. Drag and drop a Graph display icon to the Force Sensor icon.

Collect the data

1. Hold the cart in place close to the RMS and elevate the track using the wooden block.
2. Begin recording data.
3. Release the cart, allowing gravity to be the sole force of acceleration.

> ➤ ***Note:*** *If the impact is not completely inelastic (the cart bumps back from the clay stopper), repeat using a smaller angle of elevation.*

4. Stop recording.

Analyze the Data

1. Use the statistics function of *Science Workshop* to determine the maximum velocity of the cart.
2. Determine the mass of the cart
3. Calculate the momentum of the cart.
4. Use the statistics function to integrate the area under the curve.
5. Select the portion of the curve that represents the impact and record the integrated value.

> ➤ *Note: Select by clicking and dragging a box around the desired area.*

6. Compare the magnitudes of the momentum of the cart and the impulse of the collision.

Question

1. Does your experimental data show that the momentum of the cart equals the impulse of the collision? (Does $mv = \int_{t_1}^{t_2} Fdt$?)

Notes:

Experiment 3: Conservation of momentum vs. loss of kinetic energy in an inelastic collision

Purpose

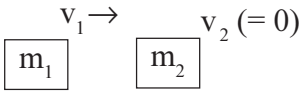
The purpose of the experiment is to quantitatively and graphically demonstrate the conservation of momentum and the simultaneous loss of kinetic energy as a result of the collision of a cart with a cart at rest.

Materials and Equipment Required

- (2) Rotary Motion Sensor (RMS) (CI-6538)
- (2) RMS/IDS Kit (CI-6569)
- (2) IDS Mount Accessory (CI-6692)
- (2) Plunger or Collision Cart (ME-9430 or ME-9454)
- pages 2 & 3 of this manual
- Dynamics Track (ME-9435A or ME-9458)
- PASCO computer interface (700)
- *Science Workshop* version 2.2 or higher
- computer

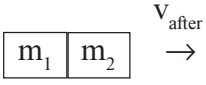
Theory

Before the collision of the two carts, the situation can be represented as follows:



where m_1 = the mass of the first cart, v_1 = the velocity of the first cart, m_2 = the mass of the second cart, and v_2 = the velocity of the second cart, which is 0.

After the collision, the carts stick together and move as one mass, as represented below:



The momentum of the system at any point in time is expressed as follows:

$$P = m_1 v_1 + m_2 v_2$$

where $m_1 v_1$ are the mass and velocity of the first cart and $m_2 v_2$ are the mass and velocity of the second. Since the momentum is conserved after the collision, the following relationship exists:

$$m_1 v_1 + m_2 v_2 = m_{after} v_{after}$$

where m_{after} = the mass of the two carts and v_{after} = the velocity of the two carts stuck together.

The total kinetic energy (KE) of the system at any moment in time is represented by:

$$KE = \frac{1}{2} m_1 v_1 + \frac{1}{2} m_2 v_2$$

In contrast to the case with momentum, KE is not conserved after the collision:

$$\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \neq \frac{1}{2}m_{after}v_{after}^2$$

Procedure

Part A — Inelastic collision of equal masses

Set Up the Equipment

1. Mount the two Rotary Motion Sensors on the IDS track using the IDS Mount Accessories, and mount the two brackets with small pulley on the IDS track (refer to the page 2 of this manual and Figure 3.1).

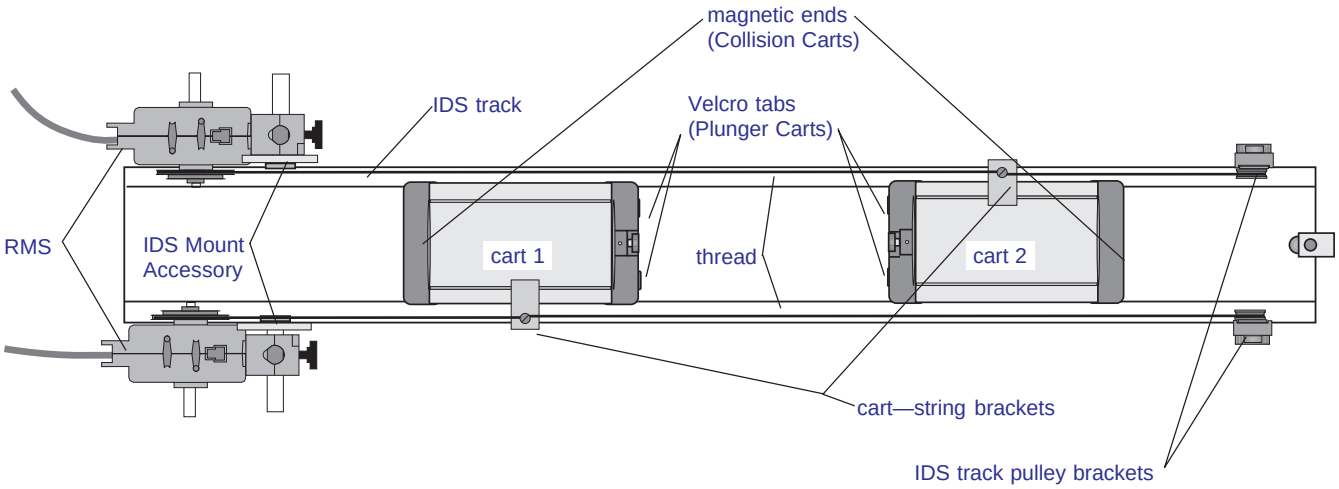


Figure 3.1
Equipment setup for experiment 3

2. Attach the cart—string brackets to the carts, measure the mass of the carts, and record in Table 3.1.

3. Place the carts on the track with the Velcro tabs (Plunger Cart) or nonmagnetic ends (Collision Cart) facing each other.

4. Thread the string as shown in Figure 3.1 and pages 2 & 3 of the manual. Make the necessary adjustments to the setup to insure that the string is unobstructed and moves freely.

5. Adjust the brackets with small pulley as necessary to insure that the thread is taunt and not slipping on the pulleys.

Set Up *Science Workshop*

1. Insert the digital plugs for the RMS connected to cart 1 into digital channels 1 & 2, and the digital plugs of the RMS connected to cart 2 into digital channels 3 & 4 of the interface box.

2. Set up the Rotary Motion Sensors in *Science Workshop* as directed in the setup section on page 3 of this manual.

3. If you are not in the setup window for the RMS, double-click on the RMS icon ( ). Set the Divisions/Rotation to **1440**. Check to be sure that **Large Pulley (Groove)** is selected in the **Linear Calibration** dialog box. Click **OK**.

4. Repeat the setup (steps 2 and 3) for the other RMS.

5. Double-click on the Sampling Options button and set the sampling rate to **50 Hz**. Click **OK**.

6. Define the calculation for display for momentum:

   - Click on the Experimental Calculator icon. Create a new calculation for momentum by clicking the New button and entering the calculation in the Expression Field using the INPUT, f(x), and keyboard buttons. Type a descriptive calculation name, such as Total Momenum1, a short abbreviation for the name, and the units of the calculation in the appropriate fields. Press **Enter** to accept the calculation entry.

     ➤ ***Note:*** *For additional information on entering calculations, refer to* ***Using Calculations*** *in the* **Users Guide for Science Workshop** *and to the section on the Experiment Calculator Window in the* ***Annotated Windows*** *section of the* **Users Guide**.

7. Define the calculation for display for kinetic energy (refer to step 6 above).

8. Make a Graph display that shows the velocity of cart 1, the velocity of cart 2, the Total Momentum of the system, and the Total Kinetic Energy of the system plotted vs. time.

   - Drag and drop a Graph icon to an RMS icon and select four calculations to display, from the **Choose Calculations to Display** pop-up menu (these selections will be modified, so it doesn't matter which calculations are selected). A Graph display with 4 sets of y-axis plots vs. an x-axis plot for time will open.

   - To set up the y-axis plot of linear velocity for cart 1, click on the Plot Input Menu button ( ) in the top y-axis plot and select Digital1 and Velocity (linVel) from the pop-up menu.

   - To set up the y-axis plot of linear velocity for cart 2, click on the Plot Input Menu button in the second y-axis plot and select Digital3 and Velocity (linVel) from the pop-up menu.

   - To set up the y-axis plot for Total Momentum, click on the Plot Input Menu button in the third y-axis plot and select calculations and the name for the momentum calculation from the pop-up menu.

- To set up the y-axis plot for Total Kinetic Energy, click on the Plot Input Menu button in the fourth y-axis plot and select **calculations** and the name for the kinetic energy calculation from the pop-up menu.

Collect the Data

1. Place the carts as indicated in Figure 3.1.
2. Start recording data.
3. Gently push cart 1 and release it, allowing it to glide to cart 2.

> ➤ ***Note:*** *The force of the push should be sufficient to propel both carts after the collision, but not hard enough to make the carts vibrate or jump the track. A smooth motion will produce the best results.*

4. Stop recording data.

> ➤ ***Note:*** *The data can be smoothed, if desired, by using the smooth function in the Experiment Calculator. To smooth data, modify your equation in the Experiment Calculator by selecting* f(x) >Special>smooth (n,x). *Set n = 8 at first. If you do not get the desired smoothing result, experiment with different values of n.*

Analyze the Data

1. Click the Autoscale Tool on the Graph display.
2. Print the graph or make a sketch of it, and indicate the point at which the carts collided.
3. Explain what is happening in each of the panels before and after the collision.
4. Use the Smart Cursor to measure:
   1) the velocity of cart 1 just before the collision.
   2) the velocity of the carts just after the collision
   3) momentum before and after the collision
   4) kinetic energy before and after the collision

   Record in Table 3.1.
5. Complete Tables 3.1 and 3.2.

Table 3.1

	m_1 (kg)	v_1 (m/s)	m_2 (kg)	v_2 (m/s)	m_{after} (kg)	v_{after} (m/s)	$m_1v_1 + m_2v_2$ (kg ms/)	$m_{after}v_{after}$ (kg m/s)
Part A							calculated / measured	calculated / measured
Part B							calculated / measured	calculated / measured

Table 3.2

	$½m_1v_1^2+½m_2v_2^2$ (N s)	$½m_{after}v_{after}^2$ (N s)	*loss of KE* %
Part A	calculated / measured	calculated / measured	
Part B	calculated / measured	calculated / measured	

Part B — Inelastic collision of unequal masses

1. Add a mass to cart 2 and repeat the data collection and analysis sections.

> ➤ ***Note:*** *You will need to redefine the calculations in the Experimental Calculator for Total Momentum and Total KE in Graph display with the new mass values.*

Questions

1. How did the inelastic collision effect the total momentum and total kinetic energy in the system?

2. What effect did friction have on the momentum and kinetic energy of the system?

3. What are other possible contributors to the variation of the experimental data from the expected (theoretical) values?

Experiment 4: Conservation of momentum and kinetic energy in an elastic collision

Purpose

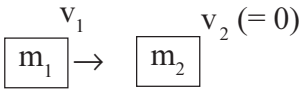
The purpose of the experiment is to quantitatively and graphically demonstrate the conservation of momentum and the simultaneous loss of kinetic energy as a result of the collision of a cart with a cart at rest.

Materials and Equipment Required

- (2) Rotary Motion Sensor (RMS) (CI-6538)
- (2) Collision Cart (ME-9454)
- (2) RMS/IDS Kit (CI-6569)
- (2) IDS Mount Accessory (CI-6692)
- pages 2 & 3 of this manual
- Dynamics Track (ME-9435A or ME-9458)
- PASCO computer interface (700)
- *Science Workshop* version 2.2 or higher
- computer

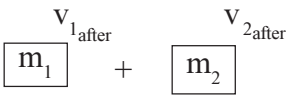
Theory

Before the collision of the two carts, the situation can be represented as follows:



where m_1 = the mass of the first cart, v_1 = the velocity of the first cart, m_2 = the mass of the second cart, and v_2 = the velocity of the second cart, which is 0.

During an elastic collision, the kinetic energy is converted to potential energy and back into kinetic energy as the carts bounce off one another. After the collision, the carts accelerate away from each other, or all the kinetic energy of one cart is transferred to the other cart, which accelerates away from the first cart has a velocity of zero. When acceleration reaches 0, the situation can be as represented below:



The momentum of the system at any point in time is expressed as follows:

$$P = m_1v_1 + m_2v_2$$

where m_1v_1 are the mass and velocity of the first cart and m_2v_2 are the mass and velocity of the second. Since the momentum is conserved after the collision, the following relationship exists:

$$m_1v_1 + m_2v_2 = m_{after}v_{after}$$

where m_{after} = the mass of the two carts and v_{after} = the velocity of the two carts stuck together.

The total kinetic energy (KE) of the system at any moment in time is represented by:

$$KE = \frac{1}{2}m_1v_1 + \frac{1}{2}m_2v_2$$

After the elastic collision, kinetic energy and momentum are preserved:

$$\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 = \frac{1}{2}m_{1_{after}}v_{1_{after}}^2 + \frac{1}{2}m_{2_{after}}v_{2_{after}}^2$$

Procedure

Set Up the Equipment

1. Mount the two Rotary Motion Sensors on the IDS track using the IDS Mount Accessories, and mount the two brackets with small pulley on the IDS track (refer to the page 2 of this manual and Figure 3.1).

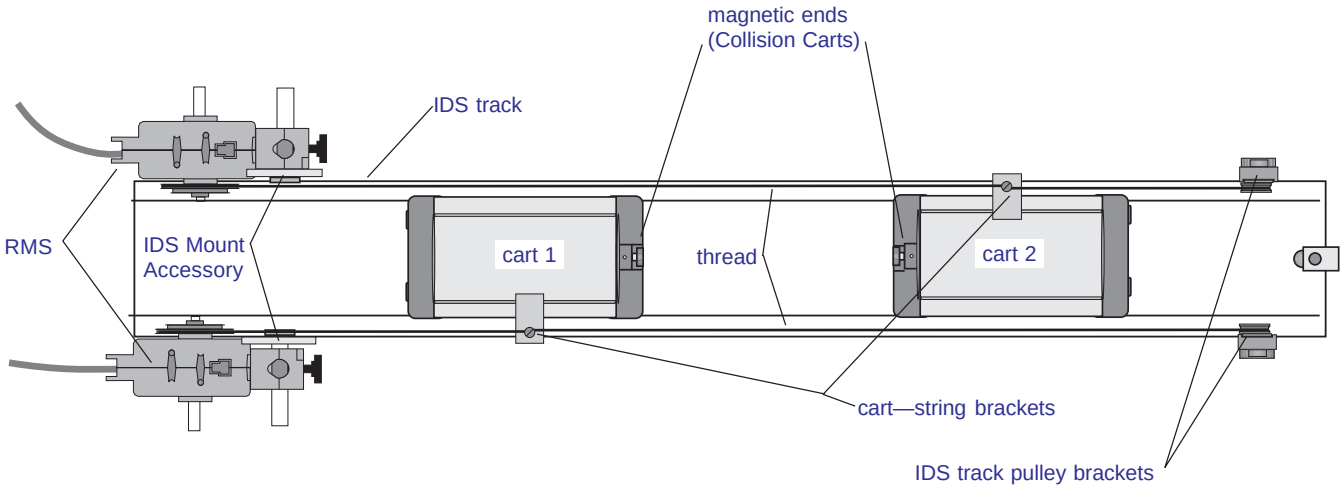


Figure 3.1
Equipment setup for experiment 3

2. Attach the cart—string brackets to the carts, measure the mass of the carts, and record in Table 3.1.

3. Place the carts on the track with the magnetic ends facing each other.

4. Thread the string as shown in Figure 3.1 and pages 2 & 3 of the manual. Make the necessary adjustments to the setup to insure that the string is unobstructed and moves freely.

5. Adjust the brackets with small pulley as necessary to insure that the thread is taunt and not slipping on the pulleys.

Set Up *Science Workshop*

1. Insert the digital plugs for the RMS connected to cart 1 into digital channels 1 & 2, and the digital plugs of the RMS connected to cart 2 into digital channels 3 & 4 of the interface box.

2. Set up the Rotary Motion Sensors in *Science Workshop* as directed in the setup section on page 3 of this manual.

3. If you are not in the setup window for the RMS, double-click on the RMS icon ( ). Set the Divisions/Rotation to **1440**. Check to be sure that **Large Pulley (Groove)** is selected in the **Linear Calibration** dialog box. Click **OK**.

4. Repeat the setup (steps 2 and 3) for the other RMS.

5. Double-click on the Sampling Options button (Sampling Options...) and set the sampling rate to **50 Hz**. Click **OK**.

6. Define the calculation for display for momentum:

   - Click on the Experimental Calculator icon. Create a new calculation for momentum by clicking the New button and entering the calculation in the Expression Field using the INPUT, f(x), and keyboard buttons. Type a descriptive calculation name, such as Total Momenum1, a short abbreviation for the name, and the units of the calculation in the appropriate fields. Press **Enter** to accept the calculation entry.

     ➤ ***Note:*** *For additional information on entering calculations, refer to* ***Using Calculations*** *in the* **Users Guide for Science Workshop** *and to the section on the Experiment Calculator Window in the* ***Annotated Windows*** *section of the* **Users Guide**.

7. Define the calculation for display for kinetic energy (refer to step 6 above).

8. Make a Graph display that shows the velocity of cart 1, the velocity of cart 2, the Total Momentum of the system, and the Total Kinetic Energy of the system plotted vs. time.

   - Drag and drop a Graph icon to an RMS icon and select four calculations to display, from the **Choose Calculations to Display** pop-up menu (these selections will be modified, so it doesn't matter which calculations are selected). A Graph display with 4 sets of y-axis plots vs. an x-axis plot for time will open.

   - To set up the y-axis plot of linear velocity for cart 1, click on the Plot Input Menu button ( ) in the top y-axis plot and select **Digital1** and **Velocity (linVel)** from the pop-up menu.

   - To set up the y-axis plot of linear velocity for cart 2, click on the Plot Input Menu button in the second y-axis plot and select **Digital3** and **Velocity (linVel)** from the

- To set up the y-axis plot for Total Momenutm, click on the Plot Input Menu button in the third y-axis plot and select **calculations** and the name for the momentum calculation from the pop-up menu.
- To set up the y-axis plot for Total Kinetic Energy, click on the Plot Input Menu button in the fourth y-axis plot and select **calculations** and the name for the kinetic energy calculation from the pop-up menu.

Collect the Data

1. Place the carts as indicated in Figure 3.1.
2. Start recording data.
3. Gently push cart 1 and release it, allowing it to glide to cart 2.

> ➤ ***Note:*** *The force of the push should be sufficient to propel both carts after the collision, but not hard enough to make the carts vibrate or jump the track. A smooth motion will produce the best results.*

4. Stop recording data.

> ➤ ***Note:*** *The data can be smoothed, if desired, by using the smooth function in the Experiment Calculator. To smooth data, modify your equation in the Experiment Calculator by selecting* f(x) >Special>smooth (n,x). *Set n = 8 at first. If you do not get the desired smoothing result, experiment with different values of n.*

Analyze the Data

1. Click the Autoscale Tool on the Graph display.
2. Print the graph or make a sketch of it, and indicate the point at which the carts collided.
3. Explain what is happening in each of the panels before and after the collision.
4. Use the Smart Cursor to measure:
   1) the velocity of cart 1 just before the collision.
   2) the velocity of the carts just after the collision
   3) momentum before and after the collision
   4) kinetic energy before and after the collision

   Record in Table 4.1.
5. Complete Tables 4.1 and 4.2.

Table 4.1

m_1 (kg)	v_1 (m/s)	m_2 (kg)	v_2 (m/s)	$m_{1_{after}}$ (kg)	$v_{1_{after}}$ (m/s)	$m_{2_{after}}$ (kg)	$v_{2_{after}}$ (m/s)	$m_1v_1 + m_2v_2$ (kg m/s)	$m_{1_{after}}v_{1_{after}} + m_{2_{after}}v_{2_{after}}$ (kg m/s)
								calculated / measured	calculated / measured

Table 4.2

$\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$ (N s)	$\frac{1}{2}m_{1_{after}}v_{1_{after}}^2 + \frac{1}{2}m_{2_{after}}v_{1_{after}}^2$ (N s)
calculated / measured	calculated / measured

Questions

1. How did the elastic collision effect the total momentum and total kinetic energy in the system?
2. What effect did friction have on the momentum and kinetic energy of the system?
3. What are other possible contributors to the variation of the experimental data from the expected (theoretical) values?

Teacher's Notes

Experiment 1

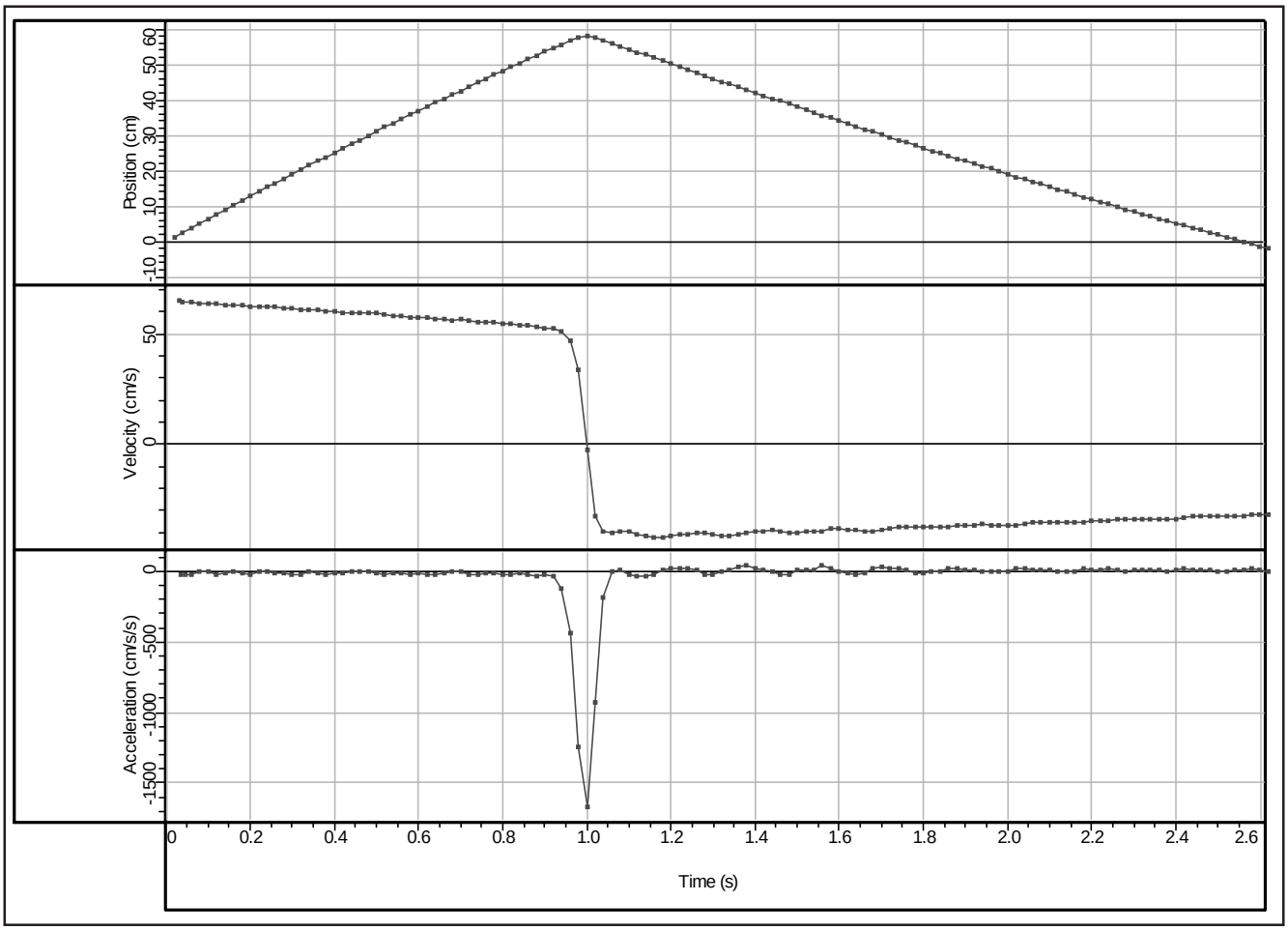


Figure TN-1
Schematic representation of typical experimental results for Experiment 1.

Questions

1. Students can use the Smart Cursor to find the velocity and acceleration of the cart just before the collision.

2. During the collision, the velocity moves from positive, through zero, to negative. When the velocity is negative, the cart is moving in the opposite direction.

3. During the collision, the acceleration varies from zero to negative and then back to zero as the cart rebounds in the opposite direction.

Experiment 2

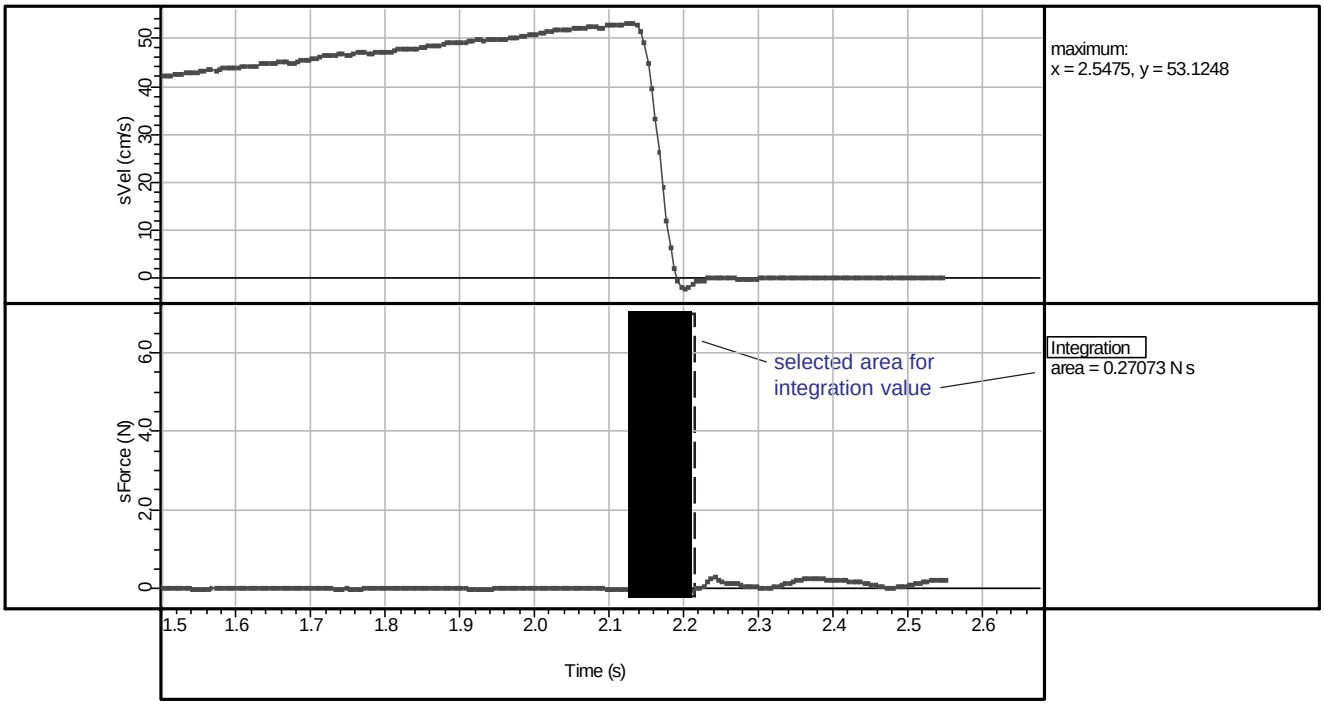


Figure TN-2
Schematic representation of typical experimental data for Experiment 2 (data smoothed).

Listed below are some typical results for Experiment 2.

Value for integration under the selected portion of the Force curve: 0.27 N s

mass of cart = 0.5 kg
V_{max} = 0.54 m/s
momentum = mv = 0.27 kg m/s (N s)

Formula for smoothing data (set in the Experimental Calculator):

Force = smooth(8,@A.Force)
Velocity = smooth(8,@1.linVel)

Question

1. The students' data should show that the momentum of the cart equals the impulse of the inelastic collision: $mv = \int_{t_1}^{t_2} F dt$.

Experiment 3

Part A—Inelastic collision of carts with equal mass

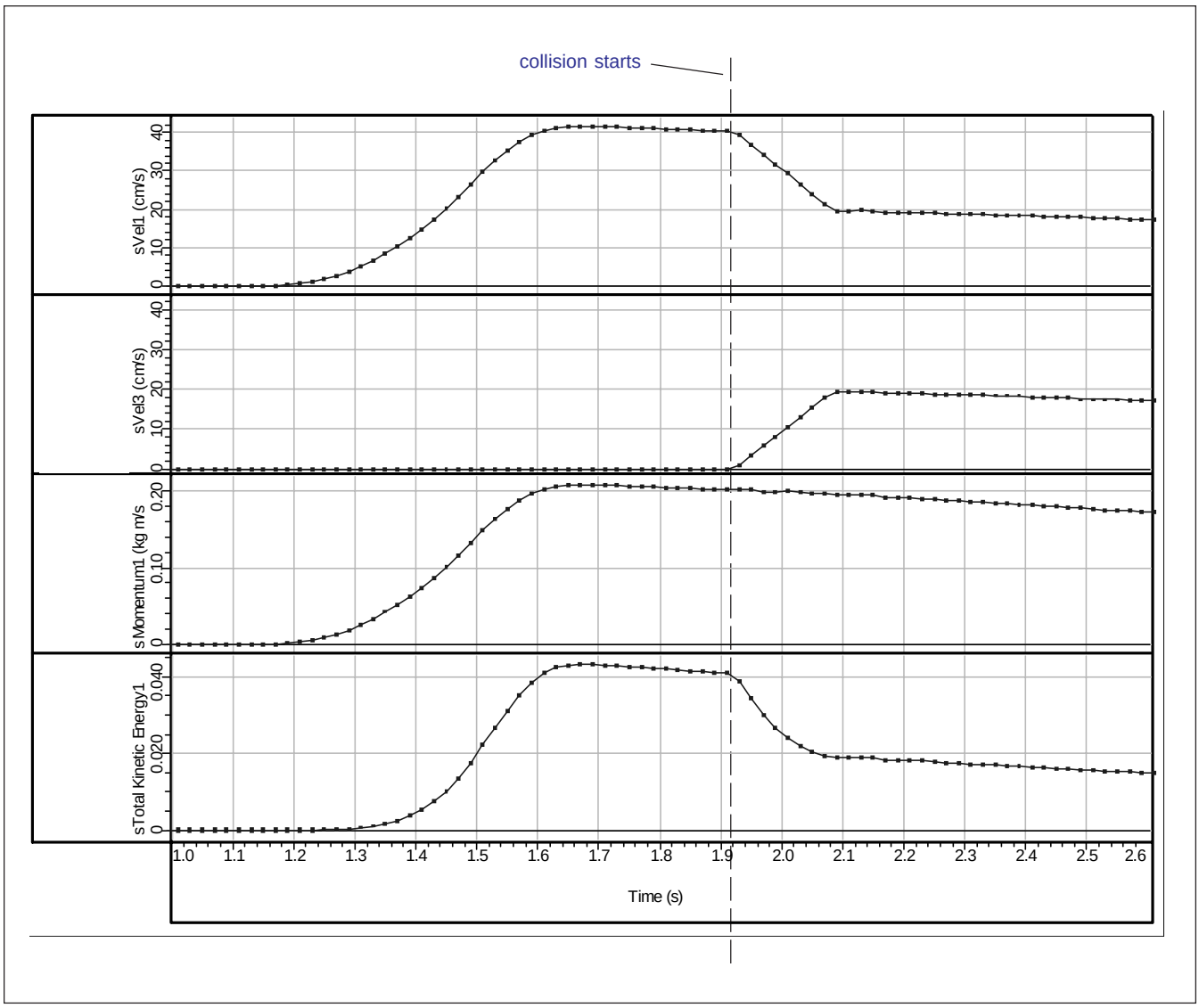


Figure TN-3
Typical experimental results from Part A of Experiment 3 (smoothed).

Equations entered into the Equation Field of the Experimental Calculator:

Formulae for Momentum and Total Kinetic Energy:

- *Total Momentum*, Part A: .51*@1.linVel*.01+.46*@3.linVel*.01
- *Total KE*, Part A: .51*(.5*(@1.linVel*.01)^2)+.5*(.46*(@3.linVel*.01)^2)

Formulae for smoothing data:

- *Total Momentum,* Part A *(smoothed)*: smooth(8,Momentum1)
- *Total KE*, Part A *smoothed*: .5*(.51*(smooth(8,@1.linVel)*.01)^2)+.5*(.46*(smooth(8,@3.linVel)*.01)^2)

Part B—Inelastic collision of carts with unequal mass ($m_1=\frac{1}{2}m_2$)

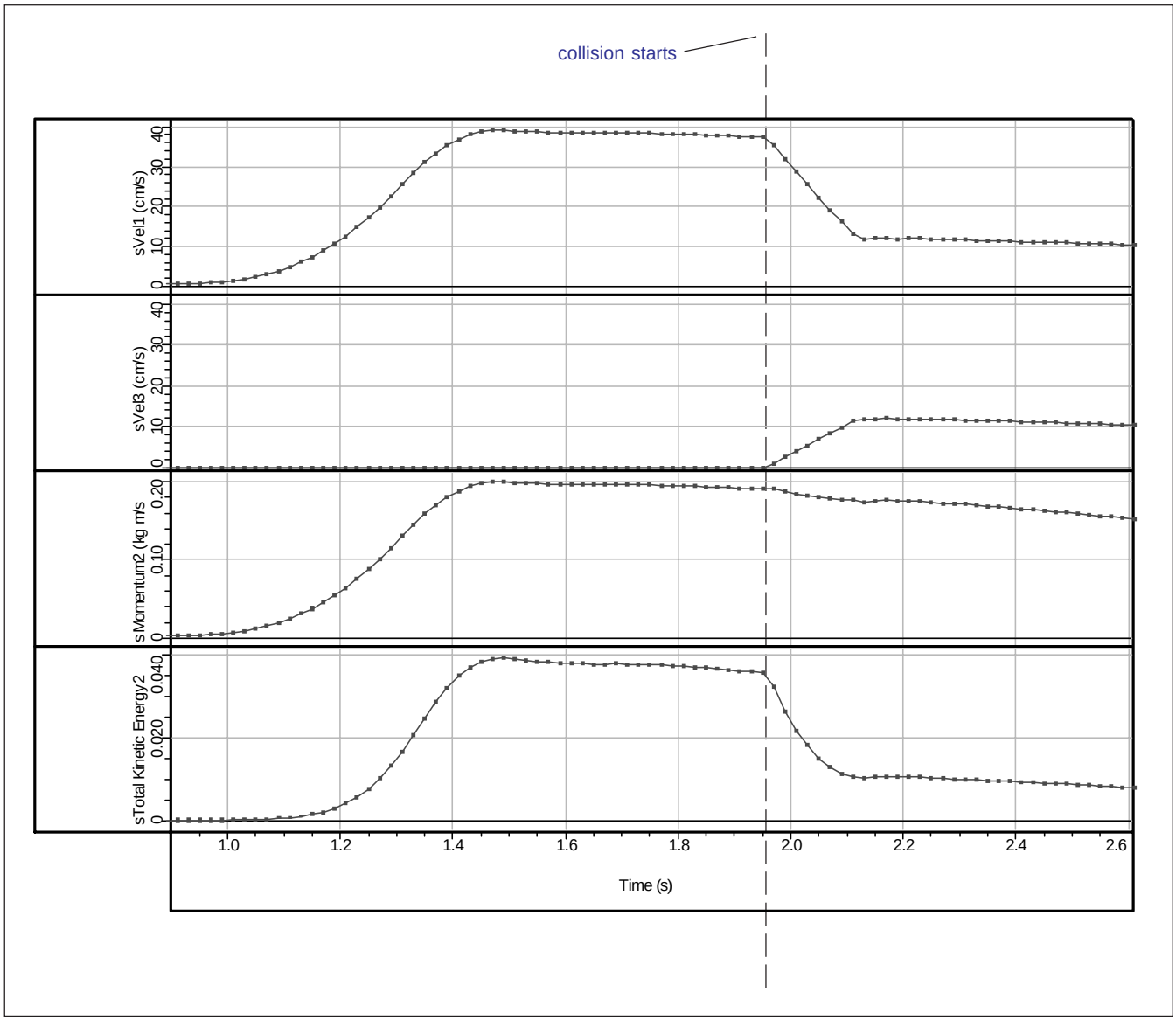


Figure TN-3
Typical experimental results from Part B of Experiment 3 (smoothed).

Equations entered into the Equation Field of the Experimental Calculator:

Formulae for Momentum and Total Kinetic Energy:

- *Total Momentum*, Part B (Momentum2): .51*@1.linVel*.01+.96*@3.linVel*.01
- *Total KE*, Part B: .5*(.51*(@1.linVel*.01)^2)+.5*(.96*(@3.linVel*.01)^2)

Formulae for smoothing data:

- *Total Momentum, smoothed* (Part B): smooth(8,Momentum2)
- *Total KE*, *smoothed* (Part B): .5*(.51*(smooth(8,@1.linVel)*.01)^2)+.5*(.96*(smooth(8,@3.linVel)*.01)^2)

Table 3.1

	m_1 (kg)	v_1 (m/s)	m_2 (kg)	v_2 (m/s)	m_{after} (kg)	v_{after} (m/s)	$m_1v_1 + m_2v_2$ (kg ms/)	$m_{after}v_{after}$ (kg m/s)
Part A	0.51	0.40	0.46	0	0.96	0.19	calculated 0.20 / measured 0.20	calculated 0.18 / measured 0.19
Part B	0.51	0.37	0.96	0	1.5	0.12	calculated 0.19 / measured 0.19	calculated 0.18 / measured 0.18

Table 3.2

	$½m_1v_1^2+½m_2v_2^2$ (N s)	$½m_{after}v_{after}^2$ (N s)	*loss of KE* %
Part A	calculated 0.041. / measured 0.041	calculated 0.017 / measured 0.018	59
Part B	calculated 0.035 / measured 0.035	calculated 0.011 / measured 0.011	69

Questions:

1. Total momentum is unchanged after the collision, but the total KE drops significantly after the collision.

2. Friction gradually reduced both the total momentum and total KE until both reach zero. Friction reduced the momentum and KE more rapidly in the system with more mass (Part B).

3. Other variables include vibration in the system and a small amount of elasticity in the collision.

Experiment 4

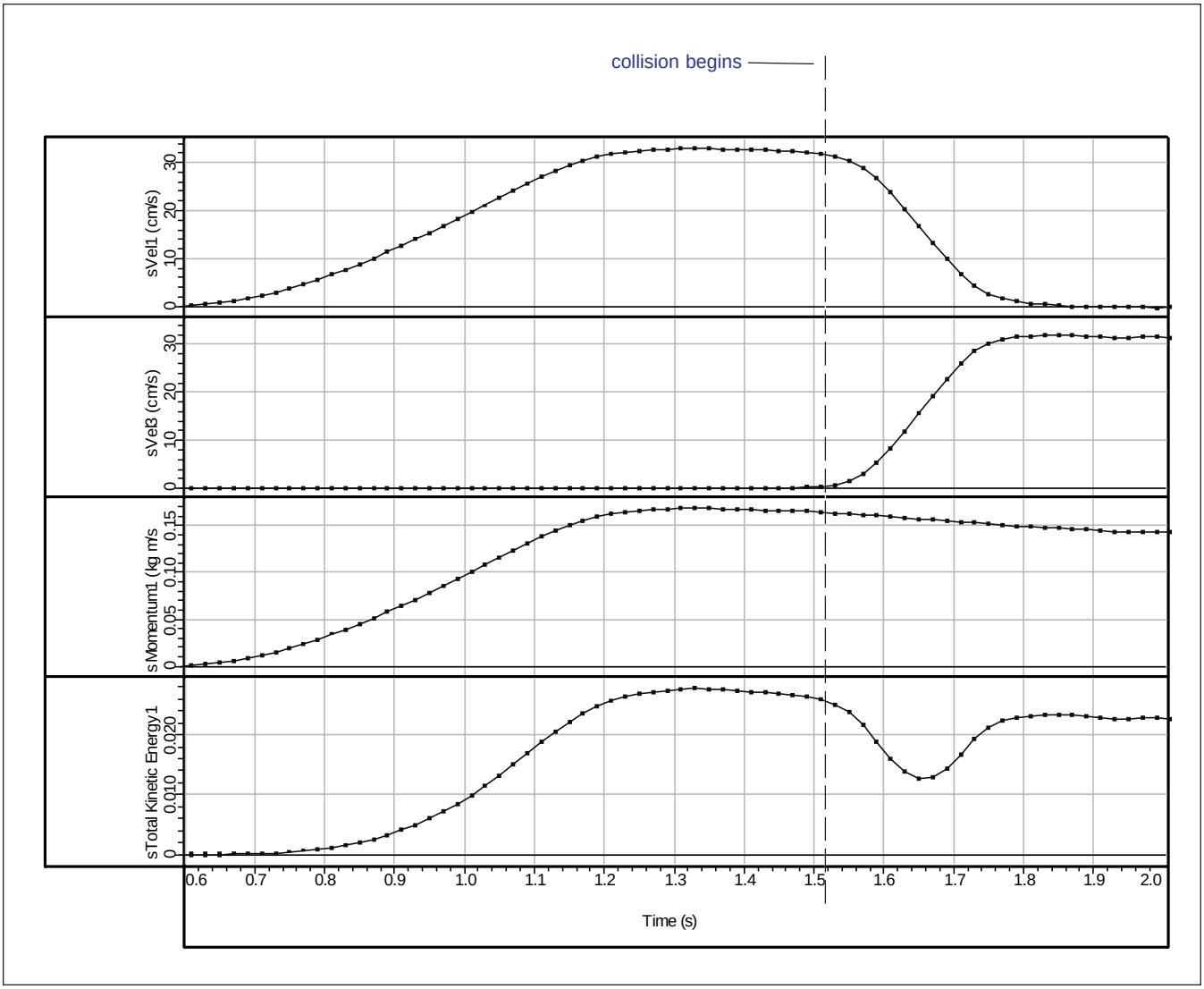


Figure TN-4.1
Typical results for Experiment 4 (smoothed)

Equations entered into the Equation Field of the Experimental Calculator:

Formulae for Momentum and Total Kinetic Energy:

- *Total Momentum*, Part A: .51*@1.linVel*.01+.46*@3.linVel*.01
- *Total KE*, Part A: .51*(.5*(@1.linVel*.01)^2)+.5*(.46*(@3.linVel*.01)^2)

Formulae for smoothing data:

- *Total Momentum,* Part A *(smoothed)*: smooth(8,Momentum1)
- *Total KE*, Part A *smoothed*: .5*(.51*(smooth(8,@1.linVel)*.01)^2)+.5*(.46*(smooth(8,@3.linVel)*.01)^2)

Table 4.1

m_1 (kg)	v_1 (m/s)	m_2 (kg)	v_2 (m/s)	$m_{1_{after}}$ (kg)	$v_{1_{after}}$ (m/s)	$m_{2_{after}}$ (kg)	$v_{2_{after}}$ (m/s)	$m_1v_1 + m_2v_2$ (kg m/s)	$m_{1_{after}}v_{1_{after}} + m_{2_{after}}v_{2_{after}}$ (kg m/s)
0.51	0.31	0.46	0	0.51	0	0.46	0.32	calculated 0.16 / measured 0.16	calculated 0.15 / measured 0.15

Table 4.2

$\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$ (N s)	$\frac{1}{2}m_{1_{after}}v_{1_{after}}^2 + \frac{1}{2}m_{2_{after}}v_{1_{after}}^2$ (N s)
calculated 0.025 / measured 0.026	calculated 0.024 / measured 0.023

Questions:

1. Both total momentum and total kinetic energy are conserved after the collision, but the total KE temporarily drops (having been converted to potential energy during the first half of the elastic collision) and then rises (as potential energy is converted to kinetic energy in the second half of the elastic collision.

2. Friction gradually reduced both the total momentum and total KE until both reach zero. Friction reduced the momentum and KE more rapidly in the system with more mass (Part B).

3. Other variables include vibration in the system and mechanical effects.

Technical Support

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If you have any comments about the product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, please tell us. PASCO appreciates any customer feedback. Your input helps us evaluate and improve our product.

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web: www.pasco.com

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➤ If your problem is with the PASCO apparatus, note:

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- Approximate age of apparatus;
- A detailed description of the problem/sequence of events (in case you can't call PASCO right away, you won't lose valuable data);
- If possible, have the apparatus within reach when calling to facilitate description of individual parts.

➤ If your problem relates to the instruction manual, note:

- Part number and revision (listed by month and year on the front cover);
- Have the manual at hand to discuss your questions.